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COMPARISON OF TCAC AND MANUAL AUDIOMETRY

April 1977

Final Report for Period April 1975-December 1976

USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

NOTICES

This final report was submitted by personnel of the Otolaryngology Branch, Clinical Sciences Division, USAF School of Aerospace Medicine, Aerospace Medical Division, AFSC, Brooks Air Force Base, Texas, under job order 7755-17-03.

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This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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Hearing threshold level was measured with Tone-Count Audiometric Computer (TCAC) audiometry and with manual audiometry on 100 subjects. TCAC yielded higher threshold at 3000, 4000, and 6000 Hz, with the average differing by about 2 dB except at 6000 Hz for the left ear, which average differed by about 5 dB. At 500, 1000, and 2000 Hz an interaction between technic and test order emerged; TCAC and manual threshold appeared the same when TCAC was given first, but TCAC poorer when manual was tested first. This study established that TCAC audiometry is comparable with manual audiometry for hearing conservation and physical standards purposes.

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COMPARISON OF TCAC AND MANUAL AUDIOMETRY

INTRODUCTION

The need for improved pure-tone threshold audiometry in the U.S. Air Force continues to exist. The Tone-Count Audiometric Computer (TCAC) (1, 2) was devised in an effort to provide this improvement. The need is primarily associated with the Air Force Hearing Conservation Program, which has been expanding in impact since publication of a new regulation (3). This new regulation, replacing a 17-year-old one (4), stimulated a general increased interest in hearing conservation and called for more audiometry than was previously required. Every U.S. Air Force member, military and civilian, who routinely works in potentially hazardous noise areas, is given a reference audiogram and followed up at least annually as long as the potential auditory risk exists. If a significant threshold shift emerges on an annual audiogram, two followup tests, after 15- and 40-hour auditory rest periods, are given to verify the shift. If the shift is confirmed, the person will usually be placed in a detailed followup program which includes up to five monthly audiograms. This total monitoring audiometry program depends on accurate evaluations. Since an individual may be tested at different locations and with different audiometers and/or examiners at the same location, standardization of test equipment and procedures is of utmost importance. The TCAC appears to offer this standardization. The purpose of this study was to determine whether or not TCAC audiometry compared favorably with the manual audiometry now in use.

PROCEDURE

TCAC and conventional manual audiometry were administered to each of 100 subjects who were patients on the Aeromedical Consultation Service at the USAF School of Aerospace Medicine, Brooks Air Force Base, Texas. With half the subjects, TCAC was done first, and manual audiometry was done first with the other half. Both tests were conducted with the subject in the same small anechoic chamber and the audiometers in an adjacent control room.

Manual Audiometry

Manual audiometry was done basically according to the Carhart and Jerger (5) preferred method for clinical determination of pure-tone thresholds. Steps in this study began at 30-dB hearing threshold level (HTL) at each pure-tone frequency. If no response was obtained, the intensity was increased in 15-dB steps until a good, correlated response was obtained. As soon as a good response was obtained, the intensity was decreased by 10 dB for the next presentation. Any failure to correctly respond was followed by a 5-dB increase. This procedure, down by 10's and up by 5's, continued until two responses were obtained at the same HTL following a 5-dB increase. That HTL was then designated threshold, and the operator changed to the next pure-tone frequency.

Tone-Count Audiometric Computer

The Tone-Count Audiometric Computer testing has been described by Meyer, Sutherland, and Brogan (1). The device is essentially an automatic tone-count response audiometer that is operated by a dedicated computer. (The TCAC was designed to present 1, 2, 3, or 4 tone pulses for each presentation. In several informal preliminary studies, however, a common complaint of listeners was that some of the pulse trains were too long and caused confusion; therefore, the 4-pulse presentation was eliminated for this study.) The subject responds by pressing the numbered button corresponding to the number of pulses he thinks he hears. The number of pulses for any given condition is determined by a pseudorandom number generator; there is no preliminary "listen" signal. Each tone pulse is about 180 msec in duration (on time), and multiple pulses are separated by about 180 msec (off time). The rise-decay time is about 25 msec. The time between presentation is about 1.8 seconds, which includes a score period of about 1.5 seconds. If a correct response does not occur within this score period, an incorrect response is assigned and the next presentation is made.

Intensity adjustments leading to threshold differ only slightly from those recommended by Carhart and Jerger. Sample threshold-finding sequences with the TCAC are in Table 1. The initial presentation for each frequency

TABLE 1. SAMPLE TCAC HEARING-THRESHOLD-LEVEL SEARCHES

a.

	HTL (dB)	Correct response
1.	30	yes
2.	20	yes
3.	10	no
4.	15	no
5.	20	yes
6.	10	no
7.	15	no
8.	20	yes

Threshold - 20 dB

b.

	HTL (dB)	Correct response
1.	30	no
2.	45	no
3.	60	yes
4.	50	no
5.	55	yes
6.	45	no
7.	50	no
8.	55	yes

Threshold - 55 dB

c.

	HTL (dB)	Correct response
1.	30	yes
2.	20	yes
3.	10	no
4.	15	yes
5.	5	no
6.	10	no
7.	15	no
8.	20	yes

Threshold - 15 dB

d.

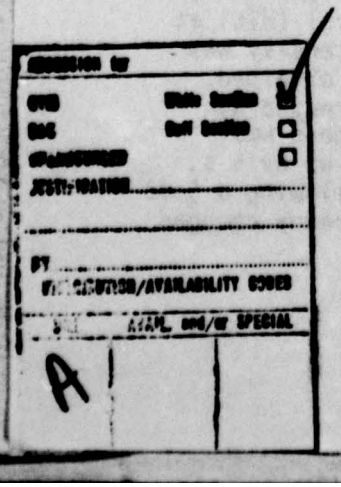
	HTL (dB)	Correct response
1.	30	yes
2.	20	yes
3.	10	yes
4.	0	yes
5.	0	yes

Threshold - 0 dB

e.

	HTL (dB)	Correct response
1.	30	yes
2.	20	yes
3.	10	no
4.	15	no
5.	20	yes
6.	10	no
7.	15	yes
8.	5	no
9.	10	no
10.	15	yes

Threshold - 15 dB



is at 30-dB HTL. If an incorrect response is made, the intensity is increased by 15-dB steps (Part b) until a correct response is made. Once a correct response is assigned, either on the initial 30 dB HTL presentation or after one of the 15-dB increases, the pattern changes. Each correct response is followed by a 10-dB decrease, and each incorrect response is followed by a 5-dB increase, until threshold is established. Threshold is the HTL at which two consecutive incorrect-to-correct ascents are in agreement. Agreement is assumed either when both "correct" responses occur at the same HTL or when the second of these responses is at a 5-dB greater level than the first. When the second response is at the higher level, the lower (first correct response) HTL is called threshold (Part c).

The TCAC has a range of HTL from 0 through 110 dB. If the HTL reaches 110 dB with no correct response, threshold is labelled 110. On the other extreme, if a correct response occurs at an HTL of 0 dB, the presentation at 0 is repeated. If a consecutive correct response occurs at 0 dB, then that value is designated as threshold (Part d).

TESTING

Both TCAC and manual audiometry were administered to all 100 subjects by the same audiologist, who is responsible for and conducts all clinical auditory tests for the USAFSAM Aeromedical Consultation Service. The left ear was always tested first; the order of presenting TCAC or manual audiometry first was alternated; and the order of frequencies was always 500, 1000, 2000, 3000, 4000, and 6000 Hz. The manual audiometry included testing at 250 and 8000 Hz for clinical purposes; however, these two frequencies were used after the six that were involved in this study, and the results are not included here.

A two-channel strip-chart recorder was used to make a permanent record of attenuator adjustments for each audiometer. The strip-chart recorder simply provided a graphic record of attenuator position throughout both tests. This record provided both a history of attenuator adjustments as threshold was sought and an indication of total test time with each audiometer. A few tests were done without the graphic recorder in operation.

Both audiometers were calibrated to ANSI-1969 specifications (6). At 6000 Hz the frequency was adjusted to be as close as possible between the two audiometers. Calibration was rechecked from time to time throughout the experiment, and a final check was made immediately following completion of testing. Calibration was satisfactory throughout the experiment.

RESULTS

Mean hearing threshold levels found with TCAC and manual audiometry for the 100 subjects are in Table 2. This table gives results separately as well as combined for the 50 who were tested first with TCAC and the 50 who were tested first with manual audiometry. These results are confusing in that a significant interaction appeared between test technic and test order for only the three low frequencies.

TABLE 2. MEAN AND STANDARD DEVIATION OF HEARING THRESHOLD LEVEL WITH TCAC AND MANUAL AUDIOMETRY

		500 Hz		1000 Hz		2000 Hz		3000 Hz		4000 Hz		6000 Hz	
		Mn	SD	Mn	SD	Mn	SD	Mn	SD	Mn	SD	Mn	SD
RIGHT EAR													
TCAC	TCAC	5.9	8.3	4.3	6.5	6.0	10.5	12.3	16.7	21.9	21.8	29.1	25.3
first	Manual	5.9	7.3	4.3	6.6	5.4	10.1	11.6	16.0	19.1	20.3	27.2	26.3
(n = 50)	Difference	0		0		.6		.7		2.8		1.9	
Manual	TCAC	7.6	8.0	6.0	7.5	9.3	13.1	17.3	20.4	23.7	21.2	29.9	23.1
first	Manual	4.8	4.9	3.5	4.2	7.2	12.4	15.0	19.2	22.9	21.2	27.8	23.5
(n = 50)	Difference	2.8		2.5		2.1		2.3		.8		2.1	
Total	TCAC	6.8	8.2	5.2	7.0	7.6	12.0	14.8	18.7	22.8	21.4	29.5	24.1
(n = 100)	Manual	5.4	6.2	3.9	5.5	6.3	11.3	13.3	17.7	21.0	20.7	27.5	24.8
	Difference	1.4		1.3		1.3		1.5		1.8		2.0	
LEFT EAR													
TCAC	TCAC	6.4	6.3	3.6	6.4	6.7	11.1	13.4	17.7	20.9	22.1	30.4	24.5
first	Manual	5.0	4.7	3.3	5.3	5.4	10.4	11.3	17.8	18.4	21.9	24.9	26.5
(n = 50)	Difference	1.4		.3		1.3		2.1		2.5		5.5	
Manual	TCAC	9.2	9.5	5.9	7.9	12.3	17.0	18.9	19.3	26.4	22.5	32.8	25.1
first	Manual	5.8	7.7	4.0	6.1	8.6	14.9	15.7	19.5	23.4	22.5	28.6	26.6
(n = 50)	Difference	3.4		1.9		3.7		3.2		3.0		4.2	
Total	TCAC	7.8	8.1	4.8	7.3	9.5	14.5	16.2	18.6	23.6	22.3	31.6	24.8
(n = 100)	Manual	5.4	6.4	3.6	5.7	7.0	12.9	13.5	18.7	20.9	22.2	26.8	26.5
	Difference	2.4		1.2		2.5		2.7		2.7		4.8	

The analysis of variance that revealed the significant interaction included order, technic, and the interaction of technic and order as variables of interest. The analysis form is shown below.

Source of Variation	Degrees of Freedom
Order of presentation	1
Subjects within order	98
Technic	1
Technic X order interaction	1
Technic X subject within order	98

The probability levels for the three analysis of variance tests are in Table 3. For the right ear, the interaction was significant ($P < .05$) for 500 and 1000 Hz. For the left ear, the interaction was significant ($P < .05$) for 500 and 2000 Hz and borderline ($P < .10$) for 1000 Hz. There was no such interaction for the three high frequencies (3000, 4000, and 6000 Hz).

TABLE 3. PROBABILITY LEVELS FOR THE THREE IMPORTANT ANALYSIS OF VARIANCE TESTS

Frequency (Hz)	Order	Technic	Order X technic interaction
	Right Ear		
500	.824	.002	.002
1000	.707	.005	.005
2000	.261	.012	.159
3000	.243	.013	.181
4000	.510	.010	.145
6000	.880	.036	.913
	Left Ear		
500	.191	.000	.034
1000	.221	.015	.073
2000	.099	.000	.025
3000	.176	.000	.608
4000	.235	.000	.655
6000	.558	.000	.292

The differences between means for TCAC and manual technics are looked at separately for high and low frequencies because of the interaction between technic and order that appeared with only the low frequencies. The TCAC mean is significantly larger ($P < .05$) than the manual mean in the low frequencies anytime the manual technic is used first. Probability levels are in Table 4. This table reveals that when the TCAC technic is used first, only one significant difference ($P < .05$) occurs and that is with the left ear at 500 Hz. The test is borderline ($P < .10$) with the left ear at 2000 Hz. Thus, when the TCAC technic is used first, the two technics give

essentially the same threshold. When the manual technic is used first, however, the threshold obtained for the low frequencies by the TCAC technic is significantly larger than that obtained by the manual.

TABLE 4. PROBABILITY LEVELS USED IN COMPARING TCAC AND MANUAL AUDIOMETRY WITHIN EACH FIRST-PRESENTATION ORDER

Frequency (Hz)	TCAC First	Manual First
	Right Ear	
500	1.000	.000
1000	1.000	.001
2000	.382	.014
	Left Ear	
500	.047	.000
1000	.627	.005
2000	.074	.000

TCAC technic means are larger than those with manual technic for the three high frequencies. Since no interaction appears, the difference between the two is the same whether the manual or the TCAC technic is used first. The test of technics in the analysis of variance (Table 3) is significant ($P < .05$) for the three high frequencies. The means from the 100 subjects for TCAC and manual-technic audiometry are in the "total" rows of Table 2.

In summary, the analysis of variance reveals that at 3000, 4000, and 6000 Hz, the TCAC technic results in higher hearing threshold levels than those obtained with manual audiometry. At 500, 1000, and 2000 Hz, the size of the difference between the two technics depends upon which one is administered first.

Complete strip-chart recordings of attenuator adjustments for both technics were made with 54 of the 100 subjects. For the TCAC testing, individual test times ranged from 2 minutes 40 seconds through 5 minutes 30 seconds--an average of 4 minutes 9 seconds. For the manual testing, individual times ranged from 4 minutes 25 seconds through 8 minutes 55 seconds--an average of 5 minutes 44 seconds. These test times include only the time during which tones were being presented and do not include instruction time.

DISCUSSION

The TCAC technic can be used in Air Force audiometry. Even though this study has revealed a statistically significant difference between thresholds obtained with TCAC and manual methods, this difference is not considered excessive.

TABLE 5. TABULATION OF DIFFERENCES IN dB BETWEEN HEARING THRESHOLD LEVEL WITH MANUAL AND WITH TCAC AUDIOMETRY (MANUAL MINUS TCAC HTL)

	Dif. (dB)	500 Hz	1000 Hz	2000 Hz	3000 Hz	4000 Hz	6000 Hz
TCAC first	15	1	1				
	10	1	1	3	2	1	2
	5	4	5	4	8	6	3
Left ear	0	26	33	25	19	21	12
	- 5	13	7	15	16	13	12
	-10	5	3	1	2	7	13
	-15			2	1	2	8
	-20				1		
	-25						
	-30				1		
	30						1
	25						1
	20				1		1
	15				1		1
	10		1	1	1	2	3
	5	15	10	8	9	10	5
Right ear	0	22	29	32	23	18	14
	- 5	12	8	4	9	8	10
	-10		2	3	2	6	7
	-15	1		2	4	4	4
	-20					1	3
	-25						
	-30					1	
Manual first	10			1	1	1	2
	5	2	7	1	6	6	1
Left ear	0	23	23	25	17	17	18
	- 5	16	16	10	15	17	13
	-10	7	2	10	9	7	14
	-15	2	2	2	1	1	2
	-20			1	1	1	
	20						2
	15					1	
	10			1		2	2
	5	2	5	7	7	10	9
Right ear	0	27	24	26	22	18	11
	- 5	14	14	5	15	13	11
	-10	5	5	8	3	6	10
	-15	2	2	3	3		5

Table 5 was assembled to provide a point-by-point comparison of each difference between threshold with manual audiometry and threshold with TCAC audiometry. For example, at 500 Hz, right ear, when TCAC was first, 22 of the 50 subjects gave the same threshold with both methods, 15 showed 5 dB better hearing with the TCAC method, 12 had 5 dB better hearing with the manual method, and 1 had 15 dB better hearing with manual. There are a total of 1200 comparisons; 6 frequencies X 2 ears X 100 subjects. Of the 1200, 525 (43.75%) thresholds were the same with both manual and TCAC audiometry. There were 961 (80.08%) that were within 5 dB and 1126 (93.83%) within 10 dB. The greatest difference between TCAC and manual thresholds was 30 dB, which occurred three times--all when TCAC was first; at 3000 Hz for the left ear, and once each at 4000 and 6000 Hz for the right ear. These differences, 94% within 10 dB, are within an acceptable range for audiometry done for hearing conservation and physical standards purposes.

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